IPSC TEST REPORT

TITLE: IGS Unit 1 Boiler Performance Test Results of the Burners and Overfire Air System

PURPOSE: State of Utah Air Quality requirement to demonstrate NOx and CO emission levels following installation of the Overfire Air System on IGS Unit 1 during its Major Outage in March of 2003.

TEST DATES: September 6- 9, 2003

REPORT DATE: September 15, 2003

SUMMARY OF RESULTS:

The results of the OFA/Burner Testing Series conducted on September 6 - 9, 2003 demonstrates excellent results for the NOx reduction of the overfire air system while minimizing CO production to an acceptable level (reference test results table and graphs).

Considerable effort was taken to tune the fuel to air ratio to each individual burner front to minimize CO creation. Efforts included installation of dynamic coal restrictors and a dirty airflow measurement and balancing routine on all 48 burners. Additionally, a burner register air flow balancing and tuning program was undertaken to refine the balancing of airflow through the inner and outer zones of the low NOx B&W burners. A flue gas analysis test grid was utilized at the economizer outlet which established a profile for CO and O2.

The four primary graphs, which shows the results of the final testing, plots control room O2 levels (indication of excess air condition at the economizer location) versus NOx levels (data from CEM instrumentation located at the stack) and CO levels (data from test analyzer also at the stack location) plotted on four different curves which represent (1) NO overfire condition (all dampers closed) and three different configurations of the overfire air dampers, (2) 1/3 dampers-full open, (3) 2/3 dampers-throttled, (4) 2/3 dampers-full open.

Reviewing the four curves, the 2/3 dampers-full open, had the best results and gives us the largest "Good Combustion Operating Range." The solid linear red line shows NOx production which increases with an increase of O2 levels (excess air). The solid blue curve shows CO production which decreases rapidly with an increase in O2 levels (excess air). CO is very sensitive to excess air levels and levels increase rapidly at the knee of this curve. However, this condition also produces the least amount of NOx.

The "Good Combustion Range" is bound by (1) State NOx limits on the top (NOx limit = 0.461 #/mbtu), (2) O2 (excess air) levels on the right (intersection of NOx curve with NOx limit), [note the OFA 2/3 dampers curve this intersection is beyond 4.0 % O2], (3) and minimum CO threshold levels on the left. These CO threshold levels are very important because they determine how low of excess air levels are allowed to drop NOx production levels down. The lowest threshold (CO 250 ppm) allows Operations the ability to meet NOx targets with changes in coal quality. Worsening coal quality raises both the NOx and CO production curves, making it more difficult to achieve targets. However, worsening coal quality was one of the primary reasons the Overfire Air System was installed, to give us the operation ability to achieve NOx targets.

PURPOSE FOR THE TESTING

IPSC had been requested by the State of Utah Air Quality to demonstrate operating conditions following the installation of the Overfire Air System (OFA) on IGS Unit 1, following it's major outage. The concern with the overfire air system is an excessive increase in CO emissions as a result of the OFA operation. The purpose of the testing is to demonstrate the actual operation with varying degrees of OFA flow rates (5% (closed), 10% (1/3 damper-open), 12% (2/3 dampers-throttle), and 14% (2/3 damper-open)) at 5 levels of O2% (1.5%, 2.0%, 2.5%, 3.0%, and 3.5% as measured from the station in-situ oxygen probes (8) (referred to as the control measurement)).

The objective of the testing is to measure CO and NOx emissions from the burners. To effectively measure and tune the burners, an elaborate test system was setup to measure key parameters at the boiler economizer outlet duct just downstream of where the duct pantlegs into two sides (east and west). This location was chosen due to it's access (horizontal run using vertical probes) and moderate gas temperatures (760° F). This site was pre-established for Boiler Performance Testing following guidelines from the American Society of Mechanical Engineers (ASME) Power

Test Codes (PTC) 4.1 Steam Generating Units and 19.10 Fine and Exhaust Gas Analyses.

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TEST METHOD OVERVIEW

The test methodology for flue gas analysis was conducted in accordance with the general procedures outlined in the ASME PTC 4.1 Steam Generators and PTC 19.10 flue and Exhaust Gas Analysis. Plant instrumentation, where possible, was utilized for the tests. Calibrated gas analyzers were connected to test probes inserted into test taps on the ductwork to obtain samples for the analysis of flue gases. The flue gas samples were mixed, chilled, dryed and filtered before analysis.

Each test point was unique varying OFA flow (four configurations) and O2 levels (five points) to establish needed CO and NOX curves. Each test was one to three hours in duration (with 1 hour of very stable conditions). Coal samples were taken during each test period. Prior to start of each test, fly ash hoppers were to have been emptied. At the end of each test, fly ash samples were collected. Between each test period, operating variables were changed and soot blowing completed to maintain target main steam and reheat temperatures.

TEST CONDITIONS

A summary of the test conditions and results can be found in Table XXX OFA Test Conditions. Each test was conducted for a nominal one and a half to two hour period. Typically the first hour was to change operating conditions. The target was to achieve one hour of stable operating data, some tests were lengthened in duration to achieve that goal.

PI and Test Grid data was collected electronically every 30 seconds. CEM data is summarized and made available of 15 minute intervals.

DATA COLLECTION

Test data collection consisted of information from the following locations and sources

1) utilizing plant data from the data historian of PI system which collects date from the Foxboro Control System and information computer
2) special flue gas test grid established at the boiler economizer back pass utilizing leased high precision flue gas analyzers to read O2, C), N) & CO2
3) flue gas probe at the stack (CEM analyzer sample location)
4) field data collection points
5) coal sample collection
6) flyash sample collection
7) CEM data

TEST SETUP- FLUE GAS TEST GRID AT THE ECONOMIZER OUTLET DUCT

The flue gas test grid was setup at the boiler economizer outlet duct which can be accessed on the 11^{th} floor. 14 test probes (7 per side) are utilized, but each probe assembly actually has 4 probes at 4 different depths. This arrangement establishes a grid array with 28 points per side, with a total of 56 points.

Each individual sample point is plumbed to a plexiglass XXX bubblier (can observe sampling rates) where it mixed with half of one sides samples. The water bath initially cools and filters the flue gas. The sample is then chilled in an ice bath with a knockout bottle (collect condensate) ran through a vacuum pump desiccant filter and sent through an air filter. The flue gas sample is then taken slip stream via a flow regulator per each analyzers requirement. Samples are then analyzed separately for CO (2) (low/high ranges). O2, CO2 and NOx. The data is collected via a Data Acquisition System and Lap top computer and then saved to a spreadsheet. This arrangement was also used for individual point profiling of the economizer outlet duct.

TEST SETUP- FLUE GAS TEST GRID AT THE STACK

Additionally, a CO analyzer was stationed at the stack to analyze averaged flue gas conditions at the <u>355</u> foot level. This is the same level as the CEM analyzers. The sample was extracted via probe and ran thru a double chiller before the analyzer.

TEST PERSONAL

All testing was conducted by IPSC Engineering Services personnel. The Test Coordinator was Aaron Nissen, Engineering Supervisor. Mr. Nissen is a licensed Professional Engineer (PE) with the state of Utah and has 23 years of utility performance testing experience.

Test Coordinator-
    Aaron Nissen, Engineering Supervisor, PE
Analyzers & Test Grid-
    Garry Christensen, Senior Engineer, PE
    Rob Jeffery, Senior Analyst
Technical Support & Coal Sampling-
    Dave Spence, Senior Engineer, PE
    Bernell Warner, Draftsman
Flyash Sample Collection-
    ISG, Rod Hansen, Rick Fowles, Kurt Aldredge
OFA System Controls and Dampers-
    Ken Neilson, Senior Engineer, PE
    Phil Hailes, Engineer

Babcock Power, Technical Support-
Dan Coats, Senior Field Engineering Manager

QUALITY ASSURANCE/ QUALITY CONTROL

Test analyzers at the stack and economizer outlet were calibrated at the beginning and end of each test series (day). Calibration gases were primary gas standards.
Calibrations on station instrumentation were completed prior to the testing. Coal feeders were rotated out two weeks prior to the test to conduct restrictor installation and feeder calibrations. Station O2 probes are calibrated on a weekly basis on a Preventative Maintenance program.

COAL SUPPLY

Coal source and supply were kept consistent during the test series to ensure emission variations were no a result of changes in fuel quality.

COAL SAMPLES

Coal samples were collected throughout the test period from each of the seven pulverizer coal feeders. Special coal sample test taps were installed above each feeder inlet below the coal silo down spout to get representative test samples.

Coal sample size was approximately 3 quarts taken from each of the 7 feeders. This totaled 5 gallons which was then sealed and taken to the coal lab.

Proximate and ultimate coal analysis was conducted by IPSC's in-house coal lab following ASTM procedures.

FLY ASH SAMPLES

Fly ash samples were collected from most of the performance tests. Maintenance had the fly ash system out for several of the tests. ISG (fly ash contractor) collected the fly ash samples. IPSC Operations pulled down the hoppers prior to each test period (beginning of each day) and between each test period.

Fly ash analysis was performed both by ISG utilizing a loss on ignition (LOI) abbreviated test and by IPSC utilizing ASTM standards for unburned carbon content.

BOILER & OVERFIRE AIR DESCRIPTION

The steam generator at the Intermountain Generating Station is a Babcock and Wilcox (B&W) subcritical steam pressure, balanced draft, opposed fired design.

It is capable of producing 6,900,000 lbs/hour of main steam at 1005 F and 2400 psi with reheat steam of 1005 F. Utah bituminous coal is the design fuel. The coal firing equipment includes Merrick coal feeders (8) B&W MPS 89G pulverizers (8), and B&W low NOX dual register burners (48). There are 6 individual burners from each pulverizer which transport coal to 8 levels of burner rows (4 front wall rows and 4 rear wall rows) Reference Boiler cross section graphic.

The overfire air (OFA) system was installed above the top burner rows to help achieve NOX emissions targets due to a decrease in Utah coal quality (higher nitrogen content coal). The OFA system stages the combustion air to reduce flame temperatures which reduces the formation of thermal NOX. There are six OFA ports above the top burner rows plus and additional wing port installed on each side. There are eight front wall and eight rear wall OFA ports, making a grand total of 16 OFA ports. Each OFA port assembly has two sets of dampers, 1/3 and 2/3 which controls overfire air flow and velocity independently of one another. Testing was conducted with the 1/3 dampers full open, 2/3 dampers throttled and 2/3 dampers full open to determine which configuration had best NOX reduction and allowed lowest CO emissions.